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Army Command and Control Evaluation System (ACCES) Review

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The Army Command and Control Evaluation System (ACCES) was developed as a performance measurement tool for division and corps command and control. To date, ACCES has been applied to one corps and six division exercises. This report reviews the data across all division applications of ACCES and points out patterns and trends that may be significant to the whole Army. It also assesses the ACCES measures themselves, so that improvements can be made in future applications. ACCES shows great promise for becoming highly useful, not only as a measurement tool for command and control training, but also as a means of evaluating physical and operational changes in command post environment. When the data base of ACCES applications has grown somewhat, it will be useful for further development of lessons learned from division and corps training exercises.

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FOREWORD

The Fort Leavenworth Field Unit of the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI) supports the Combined Arms Center with research and development in combined arms operations and command group training. Measurement of staff performance is an issue common to research in both operations and training. Performance assessment is also essential to command group training to provide diagnostic feedback to the training audience. However, no good techniques have been available for measuring performance in this complex arena. To help fill this gap, the ARI Fort Leavenworth Field Unit undertook a developmental effort to provide a staff performance measurement tool for use at division and corps levels.

Work on this project has been conducted under a memorandum of agreement (MOA) with Combined Arms Center, Department of the Army (CACDA)-C3I: Development of Performance Measurement Methodology for Corps, Division, and Brigade Command Posts, dated July 1986; and a MOA with CATA: Development, Maintenance, and Utilization of a Data Base Containing Corps and Division Training Performance and Battle Event Data, dated March 1989. To date, this measurement tool has been applied at command group exercises conducted by six divisions and one corps. This report examines the results of the division applications to determine if patterns or trends can be detected and to evaluate the utility of this measurement tool for command group performance assessment.

EDGAR M. JOHNSON
Technical Director

ARMY COMMAND AND CONTROL EVALUATION SYSTEM (ACCES) REVIEW

EXECUTIVE SUMMARY

Requirement:

The Army Command and Control Evaluation System (ACCES) was developed as a performance measurement tool for division and corps command and control. To date, ACCES has been applied to one corps and six division exercises. The use of ACCES data has previously been limited to providing feedback to the exercising units. The purpose of the project reported here was to look at the data across all division applications to determine if patterns or trends emerged that may be significant to the whole Army. Additionally, the present project assessed ACCES measures so that improvements can be made in future applications.

Procedures:

Data from all six division exercises were used in the analysis. The decision was made to eliminate the corps data from the analysis because many of the corps scores differed substantially from those of the divisions. Due to the exploratory nature of the early ACCES applications, measures were frequently revised and redefined. Of the 43 measures that an ACCES application yields, 11 measures were found and collected and reduced in a consistent fashion across all applications. An additiona nine measures were found and collected consistently across the last five applications. Daily and overall scores for each of these 20 measures were extracted from the final reports produced for each exercising unit. The analysis of these data focused on uncovering trends in the scores and on the measurement quality of the measures themselves. Because of the small number of applications available, the statistical analyses were mostly descriptive in nature.

Findings:

The data obtained from these ACCES applications have provided preliminary insights into the general strengths and weaknesses in command and staff processes. The divisions studied performed well in their ability to involve multiple staff members in the formulation of clear and comprehensible plans in accordance with their commander's guidance and to disseminate those

plans in a timely manner. Their performance was relatively weaker in the areas of thoroughness of briefings and accuracy with which forces were plotted on command post maps.

The most debilitating problem found with the ACCES measures is the reliance upon percentage figures rather than base rate information. Additionally, several measures were found to perform unsatisfactorily. Correcting these defects will be the focus of future work efforts.

Utilization of Findings:

This review has found evidence of a command and control measurement methodology that shows great promise for becoming highly useful, not only as a measurement tool for command and control training, but as a means of evaluating physical and operational changes in the command post environment. Additionally, after the data base of ACCES applications has grown somewhat, this information will be useful in further development of lessons learned from division and corps training exercises.

ARMY COMMAND AND CONTROL EVALUATION SYSTEM (ACCES) REVIEW

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ARMY COMMAND AND CONTROL EVALUATION SYSTEM (ACCES) REVIEW

Introduction

The command and control (C2) process is widely accepted as an essential ingredient in battlefield success, but it is a very difficult area in which to measure performance, especially at division level and above. Over the years, a number of methods have been developed to measure C2 performance at various echelons. These methods have been applied with limited success (see Garlinger and Fallesen, 1988, and Crumley, 1989). To fill this measurement gap, especially for divisions, the Fort Leavenworth Field Unit of the U.S. Army Research Institute undertook a developmental effort that resulted in the Army Command and Control Evaluation System (ACCES).

The primary focus of ACCES is on the overall performance of the division headquarters at various stages of the planning process, from the collection of information through the development and implementation of plans. The ACCES methodology treats the headquarters as an adaptive system that operates in control cycles in order to keep selected battlefield elements within expected limits. The general approach is illustrated in Figure 1. It assumes that the headquarters performs a number of processes in order to support decisionmaking and implementation. Additionally, in order to provide a complete evaluation of command and control, ACCES also looks at the performance of the individual functional cells within a division headquarters, as well as the interactions among functional cells. Individual ACCES measures will be discussed in later sections of this paper.

To date, ACCES has been applied in exercises conducted by six divisions and one corps. Thus far, use of the data generated during ACCES applications has been limited to providing performance feedback to the exercising units. The purpose of the project reported here was to look at the data across the set of division applications in order to determine patterns or trends that may have significance to the whole Army. The following sections of this report will describe the ACCES measures analyzed and the analysis process used. C2 lessons learned that have emerged from this analysis will be discussed, as well as weaknesses found in the ACCES measures themselves. The report will conclude with recommendations for future work to improve ACCES in order to 1) provide better C2 performance feedback to units, and 2) continue development of a tool for examination of the C2 process.

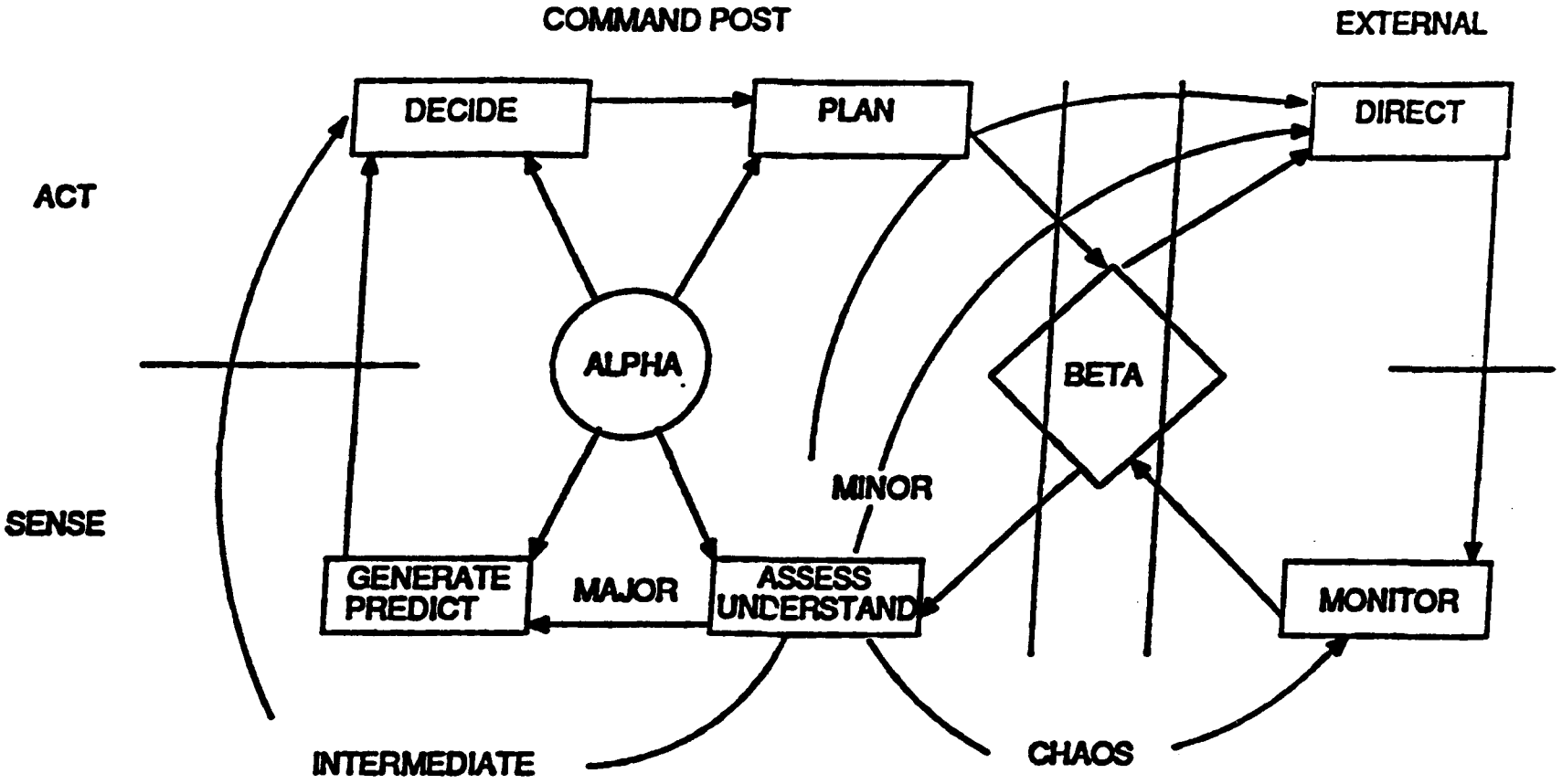

Figure 1. The command post as an adaptive control system.

Procedures

Exercise Data Base

There have been seven applications of the ACCES methodology to Army training exercises since late 1986. The first six of these were division exercises and the last was a corps exercise. The results of the division applications were reviewed during our analysis.

The first two division applications were performed in conjunction with an Operational Test and Evaluation Agency (OTEA) field evaluation. At this time, the ACCES methodolody was still called HEAT (Headquarters Effectiveness Assessment Tool) under which title it had previously been applied in Naval Fleet exercises. The last four of the five applications were performed in conjunction with WarFighter exercises conducted by the Battle Command Training Program (BCTP) headquartered at Fort Leavenworth. One application was in conjunction with a division CPX driven by the First Battle BC wargame. The BCTP exercises are intense, computer-supported, around-the-clock exercises typically lasting five days and intended to exercise all aspects of division or corps command post operations plus those of its major subordinate commands. The First Battle BC exercise is quite similar in duration and intensity, but lacks the computer support to the exercise controllers. The six divisions analyzed represent light infantry, mechanized infantry and armored divisions executing some variation of their primary missions.

Method

The primary objective over these seven applications has been to adapt, improve, and streamline the ACCES methodology. Thus the measures, the data collection procedures, and the analysis techniques have not been uniform over the seven applications (see Crumley, 1988). Therefore, our first task was to determine which of the 43 ACCES measures were collected over all seven applications and calculated in a consistent fashion. We found eleven measures which fit these criteria and we included nine others which were handled consistently over the last five applications. These 20 measures are described in the next section.

We later decided not to use the corps application as the scores were sufficiently different from those of the divisions to at least suggest a fundamental effect of echelon on the measures. Thus we ended up with 20 measures over four to six applications.

We extracted the daily and overall scores for each of these measures from the final reports produced for each exercising unit. The foci of our subsequent analyses were to look for trends in the scores and for those measures which best discriminated among the divisions. We also looked for inconsistencies among the measures which might indicate problems in application

or interpretation of the measures. Because of the small number of applications available, little statistical analysis was performed on these data.

Measures Analyzed

The 43 measures available in the current ACCES are divided into seven categories generally corresponding to the decision cycle steps which were shown in Figure 1. The category called Overall Effectiveness includes those measures which directly assess the effectiveness of the command and control system as an adaptive coping system: whether its plans stayed intact or had to be modified, and the magnitude of changes, if required.

We were able to use four of the five measures of overall effectiveness, all measures of the assessing and understanding step, and six of the eight measures dealing with generating options and predicting (i.e., labelled "estimate" in the categorization). Only three of the seven monitoring measures met the inclusion criteria. Of the remaining 20 ACCES measures that deal with internal staff and command post interactions and compatability only two met the criteria for inclusion. Therefore we were able to use fewer than half of the ACCES measures and we have little indication of how coordination within the division staff might have affected performance on the other measures.

The following are the definitions of the measures we selected, listed under their respective categories.

CATEGORY	TITLE	DEFINITION
OVERALL EFFECTIVENESS	PLAN QUALITY	Number of plan assignments that remain in force unchanged for the intended period, expressed as a percentage of the total assignments. The assignments in a plan are: mission, assets, boundaries, and schedules. The intended period is the time stated in the implementing directive or command briefing. The time the plan is in force is the time from implementation to the time(s) the plan is changed or abandoned.
	PLAN CONGRUENCE	A minor change (incongruence) to a plan is one that requires no change to the basic plan and includes such things as adjustments to fires. A moderate change is the implementation of existing alternatives and generally includes the execution of on-order missions. Major changes are those

		involving changes in one or more of the four types of assignments (see PLAN QUALITY) and for which no previous planning has been done. Plan Congruence is the number of control cycles arising from minor incongruences plus .8 times the number of control cycles arising from moderate incongruences, expressed as a percentage of the total number of control cycles.
	PLAN CYCLE TIME	Median time used to complete the control cycle. The time is measured from the headquarters perception of an event until a directive is issued or a decision is made to do nothing.
	PLAN LEAD TIME ADEQUACY	Number of directives for which planning lead time provided to subordinates is adequate, expressed as a percentage of the total number of directives. Adequacy of lead time is defined here as meeting the generally accepted 1/3 - 2/3 rule in which the command uses no more than 1/3 of the time remaining before implementation to issue its order to subordinates.
MONITORING	ACCURACY	Number of units for which headquarters data are within the desired window, expressed as a percentage of the total number of units monitored. Accuracy is reported for enemy and own units separately. The desired window is here defined as within a radius of one kilometer from actual location for own units and within two kilometers for enemy units.
	IMPACT ON PLAN	Number of control cycles initiated because of monitoring errors, expressed as the percentage of total control cycles initiated, subtracted from 100 percent.
UNDERSTANDING	COMPLETENESS	Percentage of understandings of the enemy situation presented at formal briefings which are complete understandings (i.e., in-

		clude composition, disposition, courses of action, combat power, and activity).
	QUALITY	Number of understandings, of the situation held by the headquarters which were correct, divided by the total number of understandings. Quality scores are reported separately for enemy and own understandings.
	IMPACT ON PLAN	Number of control cycles caused by headquarter's misunderstanding of the situation, expressed as a percentage of total control cycles initiated and subtracted from 100 percent.
	UNDERSTANDING TIME	Median time from the expression of an understanding to the end of the period which the understanding covers.
ESTIMATE	MULTIPLE PLANNERS	Number of control cycles for which two or more staff members participated in the development of course(s) of action, expressed as a percentage of the total number of control cycles.
	MULTIPLE OPTIONS	Number of control cycles for which more than one possible course of action was considered, expressed as a percentage of the total number of control cycles.
	PREDICTION COMPLETENESS	Number of courses of action presented at formal briefings that include predictions of enemy reaction, degree of mission accomplishment, and residual capacity of friendly and enemy units involved, expressed as a percentage of the total number of courses of action presented.
	PREDICTION QUALITY	Number of predictions which turned out to be correct, divided by the total number of predictions recorded.

	PLAN CONSISTENCY	Number of assignments in implementing directives which do not contradict the assignment of the Commander's decision(s), expressed as a percentage of the total number of assignments in the directives.
	DIRECTIVES NOT QUERIED	Number of directives not queried by recipients, expressed as a percentage of the total number of directives.
REPORTS	INFORMATION NOT QUERIED	Number of information reports not queried by recipients, expressed as a percentage of the total number of information reports.
COORDINATION	UNDERSTANDING COMPARABILITY	Degree of agreement between cells in a node, concerning understandings of the comparable friendly and enemy situations, expressed as a percentage of all such understandi s in the network.

Lessons Learned

This section will discuss lessons learned in the two areas of concern of this study, performance of the units observed and the psychometric strengths and weaknesses of the ACCES methodology.

Unit Performance

ACCES Scores. Table 1 presents the scores on 20 ACCES measures for the six divisions which compose the sample for this study. The 20 measures presented are ones for which there was approximately uniform data collection across all units examined. The table also presents ranges and means of the measures for the divisions. In order to conceal the identity of specific divisions, they have been randomly assigned the letters A-F for presentation here.

Of the percentage (as opposed to time) scores examined, those which have the highest average score are Plan Lead Time Adequacy (M=92), Monitoring Impact on Plan (M=96), and Plan Consistency (M=98). Those which have the lowest average scores are Monitoring Accuracy - Enemy (M=55), Monitoring Accuracy - Own (M=50), Understanding Completeness - Enemy (M=52), and Prediction Completeness (M=54).

The percentage scores which have the most variability are Plan Quality (R=58), Monitoring Accuracy - Enemy (R=51), Monitoring Accuracy - Own (R=32), Understanding Impact on Plan (R=31), Multiple Options (R=39), and Prediction Quality (R=34). Although

Table 1

ACCES SCORES

ACCES PERCENTAGE SCORES	DIVISIONS A	B	C	D	E	F	MEAN (M)	RANGE (R)
1. Plan Quality	98	55	71	40	71	95	72	58
2. Plan Congruence	90	68	72	72	74	68	74	22
3. Plan Lead Time Adequacy	93	80	95	97	89	96	92	17
4. Monitoring Accuracy (Enemy)	51	26	77	74	54	50	55	51
5. Monitoring Accuracy (Own)	37	40	44	53	69	57	50	32
6. Monitoring Impact on Plan	95	100	97	94	97	95	96	06
7. Understanding Impact on Plan	98	67	86	80	90	79	83	31
8. Understanding Quality (Enemy)	87	78	73	76	72	--	77	15
9. Understanding Quality (Own)	--	73	77	80	73	--	76	07
10. Understanding Completeness (Enemy)	--	65	28	55	62	--	52	37
11. Directive Not Queried	85	93	89	86	--	89	88	08
12. Plan Consistency	100	98	98	96	--	97	98	04
13. Multiple Planners	96	83	88	84	83	93	88	13
14. Multiple Options	53	68	92	56	80	81	72	39
15. Prediction Completeness	--	69	39	40	68	--	54	30
16. Prediction Quality	81	88	64	79	54	84	75	34
17. Information Not Queried	--	81	86	83	80	--	82	06
18. Understanding Comparability	81	85	95	75	75	80	82	20
MEAN=	82	73	76	73	74	77	76	24
ACCES TIME SCORES								
19. Plan Cycle Time (median, min.)	31	20	47	42	44	35	36	27
20. Understanding Time (median, hrs.)	--	00	24	09	04	--	12	24

Understanding Completeness-Enemy has a range 37, it is not included as a measure with high variability because data were obtained from only four of the divisions in the sample. Those measures with the least variability are Monitoring Impact on Plan (R=6), Understanding Quality - Own (R=7), Directives Not Queried (R=8), Plan Consistency (R=4), and Information Not Queried (R=6).

The two time scores, Plan Cycle time and Understanding Time, are displayed at the bottom of Table 1. The mean Plan Cycle Time for divisions is 36 minutes. This is the mean of the six division times, each of which is a median of the Plan Cycle Time score for that division. This indicates that, on the average, 36 minutes elapsed between the time the divisions perceived the need for a decision and the actual dissemination of that decision. Understanding Time scores are expressed in median hours. On the average, division Understanding Time was 13 hours. However, one division scored zero (i.e. less than 30 minutes) on the Understanding Time measure which indicates that the majority of the understandings expressed by this unit concerned the immediate tactical situation. No data are available for two divisions on this measure.

Rank orderings. Six percentage scores which had ranges greater than 30 were selected for further study of the rank order of the divisions on these scores plus Plan Cycle Time, the only time measure for which there was a datum for each division. The variables with the highest ranges were chosen in order that the rank orderings would be relatively clear and unambiguous. These scores were extracted from Table 1 and are reproduced in Table 2. The ranks of the divisions on each variable are given in Table 3 with the mean rank and the range of the ranks given at the bottom of the table. Note that for the percentage scores the highest score is given the rank of "1" while for the time scores the rank of "1" is given to the lowest, or fastest.

The mean division rankings all fall in the interval of 3-4 so it would appear that none was outstanding in either direction. It is interesting to note that the one (F) with a mean of "3" had no rank of either "1" or "6" and thus also had the smallest range. Even though it was not preeminent on any of these measures it still attained the highest mean rank by virtue of never being worst.

The scores of Table 2 were correlated using Pearson's method and the ranks of Table 3 were corelated using Spearman's method. These correlations are given in Table 4 with the Spearman coefficients below the major diagonal and the Pearson coefficients above. With only six observations, the standard error of the correlation coefficient is greater than .4, so, very roughly speaking, the numbers in Table 4 may be considered known within a factor of plus or minus .8. Thus, we can, if we're willing to go out on a bit of a limb, say that there may be a negative correlation between Monitoring Accuracy (Enemy) on the one hand and Prediction Quality and Plan Cycle Time on the other. Prediction

Table 2

ACCES Scores with greatest variability

ACCES PERCENTAGE SCORES	Division A	B	C	D	E	F	MEAN (M)	RANGE (R)
1. Plan Quality	98	55	71	40	71	95	72	58
4. Monitoring Accuracy (Enemy)	51	26	77	74	54	50	55	51
5. Monitoring Accuracy (Own)	37	40	44	53	69	57	50	32
7. Understanding Impact on Plan	98	67	86	80	90	79	83	31
14. Multiple Options	53	68	92	56	80	81	72	39
16. Prediction Quality	81	88	64	79	54	84	75	34
ACCES TIME SCORES								
19. Plan Cycle Time (median, min.)	31	20	47	42	44	35	36	27

Table 3

Rank order of divisions on measures with greatest variability

ACCES Variable	Division A	B	C	D	E	F
1. Plan Quality	1	5	3.5	6	3.5	2
4. Monitoring Accuracy (Enemy)	4	6	1	2	3	5
5. Monitoring Accuracy (Own)	6	5	4	3	1	2
7. Understanding Impact on Plan	1	6	3	4	2	5
14. Multiple Options	6	4	1	5	3	2
16. Prediction Quality	3	1	5	4	6	2
19. Plan Cycle Time (median, min.)	2	1	6	4	5	3
MEAN=	3.3	4	3.4	4	3.4	3
RANGE=	6	6	6	5	6	4

Table 4

Spearman\Pearson correlations between selected ACCES variables

ACCES Variable		ACCES Variable 1.	4.	5.	7.	14.	16.	19.
1.	Pln.Qual.	1.00	-.17	-.09	.55	.15	.03	.08
4.	M.A.(Enm.)	-.19	1.00	.19	.43	.19	-.48	-.90
5.	M.A.(Own)	-.16	.20	1.00	-.07	.36	-.59	-.53
7.	UIoP	.53	.49	-.09	1.00	-.11	-.50	-.50
14.	Mult. Opt.	.04	.26	.49	-.26	1.00	-.53	-.44
16.	Pred. Qual.	.07	-.83	-.49	-.66	-.26	1.00	.78
19.	PC Time	.10	-.89	-.54	-.37	-.60	.89	1.00

Quality and Plan Cycle Time may be positively correlated.

It is important to recognize that no independent criterion exists against which to validate the ACCES scores. Without such criteria, it would be a mistake to judge that those divisions obtaining the highest overall ACCES scores were those which truly performed best. As a matter of fact, one division which was generally judged at the time of the exercise to have performed in a superior manner does not have the highest overall ACCES score, nor is it highest in three of the primary measures (Plan Quality, Plan Congruence, Plan Lead Time Adequacy). It is, however, highest in Plan Cycle Time, which on the face of it, would appear to be the poorest performance on this measure. This same division was highest on Monitoring Accuracy-(Enemy), Multiple Options, Information Not Queried, and Understanding Comparability, and it was the lowest of all divisions on Understanding Completeness-(Enemy) and on Prediction Completeness.

Of the divisions observed, no one division clearly scored higher than the others on the majority of the ACCES measures. There were, in contrast, many measures on which there seemed to be relatively little variability between the divisions. As a matter of fact, on half of the measures, the highest and lowest scoring divisions were less than 29 percentage points apart. On no measure did any two divisions differ by as much as 60 percentage points.

All divisions observed had high scores on the measure of Plan Consistency (R=100-96). This measure assessed the degree to which the Commander's guidance was incorporated into the operations plan. Apparently units had no difficulty in understanding and implementing their Commander's intent.

Scores were generally high on the measure of Plan Lead Time Adequacy, which assessed the frequency with which units were able to adhere to the doctrinal 1/3-2/3 rule for order dissemination. According to this measure, units were successful in satisfying this principle in 80-97% of the decision situations.

The divisions observed also scored well on the measure of Monitoring Impact on Plan. This measure assessed the impact of a unit's monitoring accuracy on plan execution. The results indicate that plans were generally unaffected by the units' monitoring accuracy, i.e. plans seldom had to be changed due to monitoring errors.

Also, results show that the divisions observed usually involved more than one planner in the planning process (88% of the time, on the average) and that 12% (on the average) of the directives issued were queried by the recipients.

In summary then, the divisions observed demonstrated strengths in their ability to involve multiple staff members in the formulation of clear plans in accordance with their commander's intent, and to issue them in a timely manner. Indicative of the difficulty in inferring high or low performance from these scores is the apparently small effect of monitoring errors on planning. This would appear to indicate little error in monitoring. However, that conclusion is unjustified as can be seen from low scores on the specific measures of Monitoring Accuracy - both (Own) and (Enemy). These scores, in turn, may not be what they seem, as will be discussed in a later section of this paper.

Other measures on which the divisions scored relatively low were two measures which assessed briefing quality - Understanding Completeness and Prediction Completeness. This means that the understanding and predictions were not completely or fully briefed.

ACCES Measures

This discussion will be limited to the twenty measures that appear in Table 1.

Measures of overall effectiveness. Cycle Time Adequacy is the only primary measure for which there were insufficient data for inclusion in this discussion. According to Adaptive Control System Theory upon which ACCES is built, one would expect positive correlations between Plan Quality, Plan Congruence, and Plan Lead Time Adequacy. Negative correlations would be expected between these variables and Plan Cycle Time. In other words, a division which is doing well should have consistently high scores on the three percentage based scores and low (fast) Plan Cycle Times.

One of the difficulties with relying almost exclusively on percentage measures in this context is that the frequency basis for a measure tends to vary considerably. On one occasion a score of 75% for Plan Quality may be based on 30 unchanged assignments out of a total of 40 while on another the same score could represent 300 out of 400. This problem is compounded by the fact that the overall score will always be less than any of the daily scores because of the fact that assignments can carry-over beyond a single day. Thus, for example, 50 assignments on one day and 60 assignments on the following day may represent anywhere from 60 (if all assignments carried over from the previous day) to 110 (if none did) total assignments.

One Plan Congruence problem is that it is not possible from the percentage score to know the balance among minor, moderate, and major incongruences. The purpose of this measure is to indicate the average severity of changes made to directives. By calculating the numerator as "number of minor changes plus .8 times the number of moderate changes," the absolute number of major changes was lost (until the last two exercises) and the division which issued few directives tended to be penalized compared with a division that had to issue many more directives but had the same number, or even more, of major change directives.

Perhaps an example will help to clarify the issues. Suppose we have a three phase mission. One division issues only the primary directives for each phase plus one change directive within each phase, of which two are major changes. Their Plan Congruence score is 4/6 or 67%. A second division with the same three phase mission issues five change directives per phase of which three are major changes, three moderate, and nine minor. Their Plan Congruence score is 14.4/18 or 80%, considerably higher than the other division even though they had to issue many more change directives including more moderate and more major ones. It would appear that allowing the numerator to grow with the frequency of minor changes tends to obscure the effect intended to be measured. In conjunction with total number of changes this measure of "average severity of change" is more meaningful. One is less likely to be misled by Plan Congruence of 67% and 80% when the total numbers of cycles is known (6 and 18).

We have been referring to these measures as "percentage" scores but one usually thinks of percentages as numbers which range from zero to 100. That is not the case for Plan Quality and Plan Congruence. Having no major or moderate changes would result in scores of 100%, but because of the way the measures are defined it is impossible to achieve a score of zero%. There must be at least four more total assignments than there are changes in assignments, and the total control cycles must be at least one more than the number of control cycles arising from minor, moderate, or major incongruence.

The Plan Quality score does have a unique meaning when considered in relation to Plan Congruence: Plan Quality indicates the severity of major changes only. For example, division C and D (Table 1) had the same Plan Congruence score (72) but differed considerably in their Plan Quality scores (71 vs 40). This indicates that, although the two divisions had the same average severity of change, division D had more assignment changes per major change than did division C.

The apparent purpose of Plan Cycle Time is to indicate how fast the command and control system was reacting. The distribution of cycle times is highly skewed since a large number of "minor" decisions are made instantaneously while a few "major" decisions require considerable analysis and coordination. The median of this distribution was chosen as Plan Cycle Time. However, a danger is that even most median values will equal zero because of the large number of zeros in the distribution. This, of course, then allows no meaningful comparisons between divisions, command posts, or between times at the same command post. A possible remedy for this problem would be to report separately the number of zeros and then also to report the number and median of all the remaining (non-zero) cycle times.

If we make the assumption that it takes longer to make major changes than minor ones, then Plan Cycle Time should correlate negatively with both Plan Quality and Plan Congruence. Measurement eccentricities that could drive down these correlations include the effects of a high number of "moderate" changes on Plan Congruence scores -- moderate changes are typically the execution of on-order missions that can be implemented very rapidly, perhaps faster than many minor changes which might require more coordination. Defining the communication of warning orders as ending a cycle could drive down Plan Cycle Time for "major" changes as near immediate sending of warning orders to subordinates upon receipt of a directive from higher HQ is SOP with many commands even though the final decision may require much further analysis and debate. This could reduce the negative correlation with both Plan Quality and Plan Congruence.

Plan Lead Time Adequacy is a criterion-based measure which is similar to Plan Cycle Time and helps to interpret Plan Cycle Time in terms of its operational effect. If we again assume that major changes should require more planning time than minor ones, then Plan Lead Time Adequacy should correlate positively with Plan Quality and Plan Congruence. It should correlate negatively with Plan Cycle Time. This should be the most direct and critical measure of how proactive the command is. If they are looking ahead and planning accordingly, if they are "in control of the situation" and not merely reacting to what the enemy <u>has</u> done, this score should be high. For a truly proactive command, it should be independent of the other three measures but correlate positively with Understanding Time and Prediction Time, at least.

Monitoring measures. Of the seven monitoring measures, three will be addressed in this section: Monitoring Accuracy (Enemy), Monitoring Accuracy (Own), and Monitoring Impact on Plan. The two accuracy measures are among the four having the lowest percentages of the eighteen being considered. Monitoring Impact on Plan, on the other hand, is second highest of all these measures. This would appear to be a discrepancy since one might expect inaccuracies of monitoring to require initiation of unanticipated planning cycles. However, this seeming discrepancy may be due to too stringent criteria for monitoring accuracy. In all of the exercises thus far a criterion of one kilometer accuracy for friendly units and two kilometers accuracy for enemy units has been applied. In view of the fact that a U.S. battalion task force defending in sector covers an area of between 32 and 80 square kilometers (FM 71-2), the criterion of one kilometer accuracy for locating its center of mass may be unrealistic. Given the greater uncertainty regarding the exact location of enemy units, requiring accuracy within two kilometers for locating their center of mass is even more unrealistic.

Understanding. All the understanding measures had sufficient data (at least four scores) to be included in this report: Understanding Completeness, Understanding Quality (Enemy), Understanding Quality (Own), Understanding Impact on Plan, and Understanding Time; but it may be noted from Table 1 that several of these data points are missing.

Prediction Completeness will be discussed in a later section, but it and Understanding Completeness had among the lowest scores of all the measures. This may be because of the stringent requirement that to be "complete" an Understanding must include all five of the following: composition, disposition, courses of action, combat power, and activity, and a Prediction must include: predictions of enemy reaction, degree of mission accomplishment, and residual capacity of friendly and enemy units involved. The assumption that all of these would be required every time an understanding or prediction is briefed regardless of their roles in previous briefings is somewhat ritualistic and may not be yielding the most informative measures.

Understanding Completeness cannot be directly compared with Understanding Quality (both Enemy and Own) because the latter includes all understandings whereas the former includes only those expressed in formal briefings. It might prove useful to separate the count for Understanding Quality into two parts: those perceptions expressed in formal briefings and the remainder. Doing this would yield the same measures as now and, in addition, would give a measure of quality for formal briefings.

Future Work

Data Base

As of now, the ACCES data base consists of the percentages and times given in Table 1. The percentages are the results of widely varying numerators and denominators only a few of which are now available. Many of the original logs of the observers are on hand but the possibility of reconstructing scores from these is questionable. A search is being conducted for the intermediate data sheets from which counts will be reconstructed. At that time the raw data will be entered into a file which will permit manipulations not now possible. These data will still be too sparse to permit clear statistical inferences but it will be possible to search for relationships between more basic, elemental variables than the percentages now available.

Eventually, it will be necessary to have the data base comprise several files, but for the data expected to be available in the immediate future, one should suffice. It will consist of the data which were used to calculate the percentages in Table 1, and include things like (for a specified period) Number of Control Cycles, Total Number of Assignments, Number of Assignment Changes, Number of Major Incongruences, etc. Figure 2 gives an approximation of what a record in this file would contain: on the left are given the names of the variables and on the right, for each variable is the length of the field (number of columns) necessary for that variable. Much of the detail indicated for this file will be unavailable for past exercises but all the variables for which there are data will be included. In addition, summaries of some of the variables listed for files 2-5 (see Figure 3) will be included, i.e., some of this information is expected to be available, not in the detailed form indicated here but as they have been accumulated in the past. These file definitions are intended to be more prospective than retrospective in that they define variables which will be available in future exercises but are not, for the most part, recoverable from past exercises.

Those variables in File 1 under Monitoring which have to do with Monitoring Accuracy have posed a potential security problem. The problem has to do with recording map coordinates of unit positions. The way in which the problem has been avoided in the past has been to record only whether or not a unit was plotted within a given standard of accuracy, one grid square for own and two grid squares for enemy maneuver battalions. Relatively poor performance on these variables may have been due to an overly stringent criterion. If it is possible to record amount of discrepancy between the plotted location of a maneuver battalion and its ground truth location, that should prove to be a better measure than recording whether or not some arbitrary criterion was attained. The security problem would still be avoided by

Variable		Field Length
	FILE 1:	
1.	Day (or 12 or 6 hr. period) of exercise	2
2.	Unit (A, B, C, etc.)	2
	Overall Effectiveness	
3.	# decision cycles started	3
4.	# decision cycles completed	3
5.	# decision cycles interrupted by anticipated change	3
6.	# decision cycles interrupted by major change i.e. change in mission, assets, boundary, and schedule (MABS)	3
7.	# assignments made (MABS), including changed	3
8.	# assignments changed (MABS)	3
9.	# assignments which contradict Cmdr's decision	3
10.	# directives issued	3
11.	# directives queried	3
	Monitoring	
12.	# Own Force maneuver battalions (MBs)	2
13.	# Own Force maneuver battalions plotted in DMAIN INTEL	2
14.	# OF MBs plotted within one grid square of correct	2
15.	# Own Force maneuver battalions plotted in DMAIN OPS	2
16.	# OF MBs plotted within one grid square of correct	2
17.	# OF MBs plotted on DTAC INTEL maps	2
18.	# OF MBs plotted within one grid square of correct	2
19.	# OF MBs plotted on DTAC OPS maps	2
20.	# OF MBs plotted within one grid square of correct	2
21.	# Enemy maneuver battalions (MBs)	2
22.	# Enemy MBs plotted on DMAIN INTEL maps	2
23.	# Enemy MBs plotted within two grid squares of correct	2
24.	# Enemy MBs plotted on DMAIN OPS maps	2
25.	# Enemy MBs plotted within two grid squares of correct	2
26.	# Enemy MBs plotted on DTAC INTEL maps	2
27.	# Enemy MBs plotted within two grid squares of correct	2
28.	# Enemy MBs plotted on DTAC OPS maps	2
29.	# Enemy MBs plotted within two grid squares of correct	2
30.	# Friendly units of interest	2
31.	# Friendly Units w/data outside desired time window	2
32.	# Queries re above friendly units	2
33.	# Enemy units of interest	2
34.	# Enemy Units w/data outside desired time window	2
35.	# Queries re above enemy units	2
36.	# Decision cycles initiated because of monitoring errors	2
37.	# Predictions of time at which weather will change	2
38.	# Correct weather change predictions	2
	Understandings	
39.	# Understandings of enemy situation presented at formal briefings	2
	# Understandings which include:	
40.	a. composition	2
41.	b. disposition	2
42.	c. courses of action	2
43.	d. combat power	2
44.	e. activity	2
45.	# Understandings which include all, a-e, above	2
46.	# Perceptions of the situation by headquarters	2
47.	# Perceptions correct	2
48.	# Perceptions not incorrect	2
49.	# Perceptions incorrect	2
50.	# Predictions correct	2
51.	# Predictions not incorrect	2
52.	# Predictions incorrect	2
53.	# Decision cycles initiated because of errors of understanding	2

Figure 2. ACCES data file.

Variable		Field Length
	FILE 2: CYCLE TIMES (day hr min)	
1.	Time the need for directive/decision first perceived	6
2.	Time warning order issued to subordinate command	6
3.	Time directive/decision communicated to subord. comm.	6
4.	Intended (specified) execution time of directive	6
5.	# Planners involved	2
6.	# Options considered	2
7.	# times this directive queried	2
8.	Was this cycle initiated because of monitoring error(s)? no:0 yes:1	1
	FILE 3: COORDINATION	
1.	Time necessity for coordination first perceived	6
2.	Time of decision	6
3.	Time of request or report (999 if decision was to do nothing)	6
4.	# times this request or report queried	2
5.	Response to request within desired time window? no:0 yes:1	1
	FILE 4: UNDERSTANDING TIMES (day hr min)	
1.	Time at which understanding was expressed	6
2.	End time: period of understanding	6
3.	Did understanding match ground truth? no:0 yes:1	1
4.	Was understanding "not incorrect"? no:0 yes:1	1
	Did understanding include:	
5.	composition? no:0 yes:1	1
6.	disposition? no:0 yes:1	1
7.	courses of action? no:0 yes:1	1
8.	combat power? no:0 yes:1	1
9.	activity? no:0 yes:1	1
10.	Did understanding cause initiation of a control cycle no:0 yes:1	1
	FILE 5: ESTIMATE TIMES (day hr min)	
1.	Time estimate was made	6
2.	Time directive was issued	6
3.	End of the time covered by estimate	6
4.	Number of staff members contributing to the estimate	2
5.	Number of options considered	2
	Did estimate include:	
6.	prediction of enemy reaction? no:0 yes:1	1
7.	degree of mission accomplishment? no:0 yes:1	1
8.	residual capacity of friendly units? no:0 yes:1	1
9.	residual capacity of enemy units? no:0 yes:1	1
10.	Was estimate correct? :1 not incorrect? :2 incorrect? :3	1
11.	Number of assignments in this directive	2
12.	Number of assignments which contradict the assignments of the Commander's decision	1
13.	Number of queries about this directive	2

Figure 3. Additional ACCES data files.

recording not raw location data but non-classified differences. Individual plotting discrepancies could be retained in a separate Monitoring file with mean errors recorded in File 1.

Follow-on

For ACCES applications to be carried out beginning in 1990 we anticipate a gradual clarification and "hardening" of the variables in order to eliminate as many of the ambiguities as possible. Rather than using summary percentages for investigating effects and relationships, more elemental counts will be utilized. For example, instead of: the percent of planning cycles for which two or more staff members participated in the development of alternative courses of action, we will have: the number of staff members who participated in each planning cycle. From these numbers it will be possible to make a distribution showing how many planning cycles involved one staff member, how many two, how many three, etc. It may be that two or three staff members, working together, are able generally to formulate more complete and accurate estimates than a single person working alone. However, it may be only under fairly circumscribed conditions that they can do this, therefore, we will want to be able to examine these counts according to prevailing conditions. Further, it may be that under certain circumstances it is counter-productive to have more than one (or three, or some other number) staff member(s) developing alternative courses of action. We may be able to find out if this is true and if it is, be able to specify some of the circumstances for which it is true.

It is recognized by many that there are so many factors which contribute to battle outcome that it cannot serve as a very sensitive criterion against which to evaluate command and control. Under the assumption that commanders and their staff members, by virtue of their selection, training, and experience, are not only capable of judging but in the best position to judge C2 operations in which they are involved, a very brief and direct questionnaire (see Appendix A) has been developed.

During a CPX at which ACCES is being applied, the commander and selected members of his staff could be asked to fill out this questionnaire approximately two times a day. The rebarbative nature of this kind of task is minimized by the brevity of this one. It should take no more than two minutes to complete. . . less as it becomes more familiar. If we do this and there is substantial agreement among these experts, their responses will be combined and used to elucidate ACCES measures. If there is wide diversity of responses we could try to understand why and see if there is any information in the responses which can help to clarify the nature of the ACCES measures. More likely would be results between these two extremes such as similar views within a CP which differ from those of another CP or similar views within an echelon but differing views between echelons. However that turns out, the questionnaire has a high degree of

face validity and relations between the responses to these questions and many of the ACCES measures would help to establish ACCES construct validity.

Summary and Conclusions

The analyses conducted on the data obtained from the ACCES applications studied have provided preliminary insights into the general strengths and weaknesses in command and staff processes. The divisions studied performed well in their ability to involve multiple staff members in the formulation of clear and comprehensible plans in accordance with their commander's expressed intent, and to disseminate them in a timely manner. Conversely, their performance was relatively weaker in the areas of thoroughness of briefings and accuracy with which forces were plotted on command post maps. These trends cannot be construed as absolute truth inasmuch as the sample size used in the analyses was small, and ACCES is imperfect as a measurement methodology. In addition to the purpose of exploring the possibilities in regard to the types of questions and problems for which the ACCES methodology could provide assistance in finding solutions, the present project was an attempt to examine the utility of the measures and propose fixes where possible.

As a result of the analyses conducted in this project, it has become apparent that the most debilitating problem with the ACCES methodology is the reliance upon percentage figures. For most of the uses in which the methodology could be applied, raw scores or frequency counts, rather than percentages would provide a great deal more precise and reliable information. Another of the problems noted with the measures is the unrealistic stringency with which monitoring and completeness are measured. Recommendations have been made to revise the criteria on these measures to more realistically reflect performance.

ACCES has been applied during six division exercises in approximately 18 months. This is a very short time in the developmental lifespan of a complex measurement technology, and the measurement of command and control is certainly complex. Over this time, many changes were made to the measures as well as to the data collection and analysis techniques. This evolutionary process has resulted in many improvements. However, in this review we have found several examples of ACCES measures which are still less than satisfactory. Development of improvements in the measures and procedures is the task of a follow-on contract scheduled to begin early in calendar year 1990. This review has also found evidence of a methodology which shows great promise for becoming highly useful, not only for its primary and obvious purpose but also for extensions of that purpose. In addition to providing general, overall measures of C2 at the division and corps echelons, ACCES will make it possible to evaluate physical and operational changes in the command post environment. Feasibility has been demonstrated.

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Appendix A

COMMAND AND CONTROL QUESTIONNAIRE

The following questions are designed to obtain your opinion of the quality of performance of certain aspects of the command and control system for the past 12 hours. Please answer to the best of your knowledge and from your own point of view. Each question is accompanied by a line marked from zero to 100%. The zero (left) end of the line is for extremely poor performance and the 100% (right) end is for extremely good or perfect performance. Place a single mark on the line at the position which indicates your opinion. . .toward the left for worse, toward the right for better.

How well has C2 performed the following functions?

1. Fulfill priority intelligence requirements:

0 10 20 30 40 50 60 70 80 90 100%

2. Translate commander's intent into action:

0 10 20 30 40 50 60 70 80 90 100%

3. Inform commander of progress of the battle:

0 10 20 30 40 50 60 70 80 90 100%

4. Dissemination of orders to lower echelons:

0 10 20 30 40 50 60 70 80 90 100%

5. Synchronization of entire division effort:

0 10 20 30 40 50 60 70 80 90 100%

6. Appropriate delegation of authority by senior commanders:

0 10 20 30 40 50 60 70 80 90 100%

7. Engineer planning support of commander's intent:

0 10 20 30 40 50 60 70 80 90 100%

8. Fire planning support of commander's intent:

0 10 20 30 40 50 60 70 80 90 100%

9. Coordination of combat service support:

0 10 20 30 40 50 60 70 80 90 100%

10. Lateral coordination among the division staff elements (G1, G2, G3, etc.):

0 10 20 30 40 50 60 70 80 90 100%

11. Horizontal coordination among division CPs (DMAIN, DTAC, DREAR):

0 10 20 30 40 50 60 70 80 90 100%

SUMMARY QUESTIONS:

A. During the last 12 hours, to what degree was there successful progress toward mission accomplishment?

0 10 20 30 40 50 60 70 80 90 100%

B. What is the capability of the division for continuing the mission?

0 10 20 30 40 50 60 70 80 90 100%

C. What is the enemy's capability for continuing their mission?

0 10 20 30 40 50 60 70 80 90 100%